Northern Anchovy

Kevin Fleming

Introduction

The northern anchovy, *Engralus mordax*, is a planktivorous, schooling fish that is common in bays and estuaries along the west coast of North America from Oregon to Baja California (Miller and Lea 1972).

Three subpopulations are recognized (Vrooman and others 1981). The distribution of the northern and central populations overlap outside the Golden Gate. Although fish from either population may be present in the estuary, the northern anchovies in the San Francisco Estuary seem to be more closely associated with the central population (Haugen and others 1969, Vrooman and others 1981). Members of the central population move north during the summer and south during the winter (Haugen and others 1969). Some of the movements have been extensive—tagged fish from San Francisco Bay were recovered in southern California. In addition to north-south movements, they also move offshore during fall and winter and return inshore in spring (Baxter 1967).

The northern anchovy is the most abundant species in the estuary and is an important forage fish for other resident and migratory species in the system, including salmon, jacksmelt, and striped bass. It supports a moderate commercial fishery for live bait (Smith and Kato 1979).

Although spawning occurs all year, resource limitations and environmental conditions constrain most reproduction to winter and spring at temperatures from 10 to 23 °C (Ahlstrom 1956, Brewer 1978). In the estuary, 2 spawning peaks occur, the 1st from February to April and the 2nd from July to September (Wang 1986).

Some northern anchovies mature after their 1st year at about 90 mm TL and all are mature after their 4th year and about 152 mm TL (Clark and Phillips 1952). Females may spawn batches of eggs and a large female may produce up to 130,000 eggs annually (Baxter 1967, Hunter and Macewicz 1980).

Methods

Midwater trawl data was used to describe distribution and abundance. No conspicuous cohorts were apparent from length frequency data, so separation of age–0 and age–1+ northern anchovies was based upon the length at earliest sexual maturity (about 90 mm) (Clark and Phillips 1952). Because of their low vulnerability to the net, fish <40 mm FL were not used in this analysis. Fish between 40 and 90 mm were considered age 0, and those >90 mm were considered age 1+.

The annual abundance index was calculated using February to October data. No index was calculated for 1994 because sampling with the midwater net was curtailed after April of that year.

Results

Abundance

Northern anchovy abundance was highly variable between years. The highest abundance for age–0 fish was in 1992 and the lowest in 1980. The difference was about 4 times (Figure 1A, Table 1). The indices for age–1+ fish were even more variable; the highest index in 1984 was approximately 10 times greater than the lowest in 1980 (Figure 1B, Table 2). Although no index was calculated in 1994, the above average February and March indices for both age classes suggests that the annual abundance index for that year would have been above average.

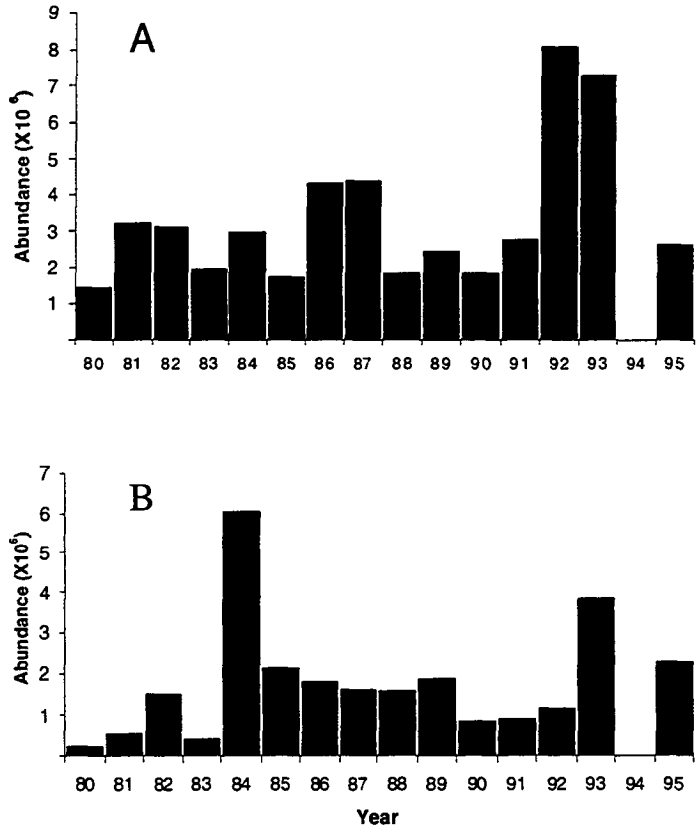

Figure 1 Annual abundance of northern anchovy: (A) age 0 and (B) age 1+. No abundance index was calculated in 1994.

Table 4 Monthly abundance indices (divided by 1000) of age-0 northern anchovy captured in the midwater trawl from 1980 to 1995. The last column is the annual index, the mean abundance from February to October. The bottom row is the average seasonal abundance from 1981 to 1988. No index was calculated for 1994.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Index
1980		54	4	53	201	7903	839	1006	2476	575	5130	2	3234
1981	15	64	3	541	474	3946	7258	3557	10734	2530	189	50	3122
1982	963	10	135	109	2149	5073	4072	6516	6762	3274	275	53	1961
1983	49	13	41	52	633	368	1087	2859	5834	6763	225	4	2964
1984	1	2	163	1633	3652	8131	3607	1878	5664	1943	52	19	1754
1985	26	22	470	2799	1166	1353	4240	691	3475	1568	1188	38	4324
1986	2	2	10	77	406	1242	27440	2910	2592	4238	5642	244	4384
1987	12	1	466	617	2469	10325	9863	8775	4254	2687	1828	12	1860
1988	4	37	1043	1602	1288	1840	3737	1089	2416	3692	929	29	2472
1989	11	15	335	1087	2619	4410	6335	2504					1837
1990		103	531	1012	2201	3427	2729	3007	2794	731			2763
1991		117	166	928	830	3543	2789	3430	7308	5758			8105
1992		13	221	3778	13825	10150	4112	10362	15114	15373			7312
1993		38	138	2566	2008	8678	7588	16453	12323	16016			
1994		135	11666	13298									2624
1995				176	6332	1154	2279		3527	2274	161	19	
1981-1988	134	19	291	929	1530	4035	7663	3534	5216	3337	1291	56	

Table 5 Monthly abundance indices (divided by 1000) of age-1+ northern anchovy captured in the midwater trawl from 1980 to 1995. The last column is the annual index, the mean abundance from February to October. The bottom row is the average seasonal abundance from 1981 to 1988. No index was calculated for 1994.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Index
1980		19	24	26	258	541	625	339	290	157	1598	0	253
1981	<1	61	1	2125	107	1297	662	315	159	94	<1	1	535
1982	123	0	8	5	5639	4911	2191	277	384	200	0	0	1513
1983	1	9	61	14	742	674	766	1084	475	33	2	0	428
1984	0	0	3	7856	11738	10012	5984	2149	12294	4240	9	0	6030
1985	2	4	76	4101	3494	1538	2467	552	3244	3580	960	0	2117
1986	1	1	2	19	3338	1250	6582	1171	297	3603	1450	4	1807
1987	1	<1	509	226	7945	1829	2313	1146	416	11	25	1	1599
1988	2	12	529	5782	2366	1839	2023	946	293	242	8	4	1559
1989	2	2	289	1665	5732	986	3000	1190					1837
1990		491	525	1642	1291	1311	1349	832	165	22			848
1991		43	99	1246	498	1519	1162	786	2633	167			906
1992		2	135	2450	1210	3972	1014	872	696	77			1159
1993		14	231	3002	9227	10643	8259	1147	134	1635			3810
1994		47	5341	2144									
1995				2	4677	4524	3694		570	126	21	1	2265
1981-1988	16	11	148	2516	4421	2919	2874	955	2195	1500	307	1	

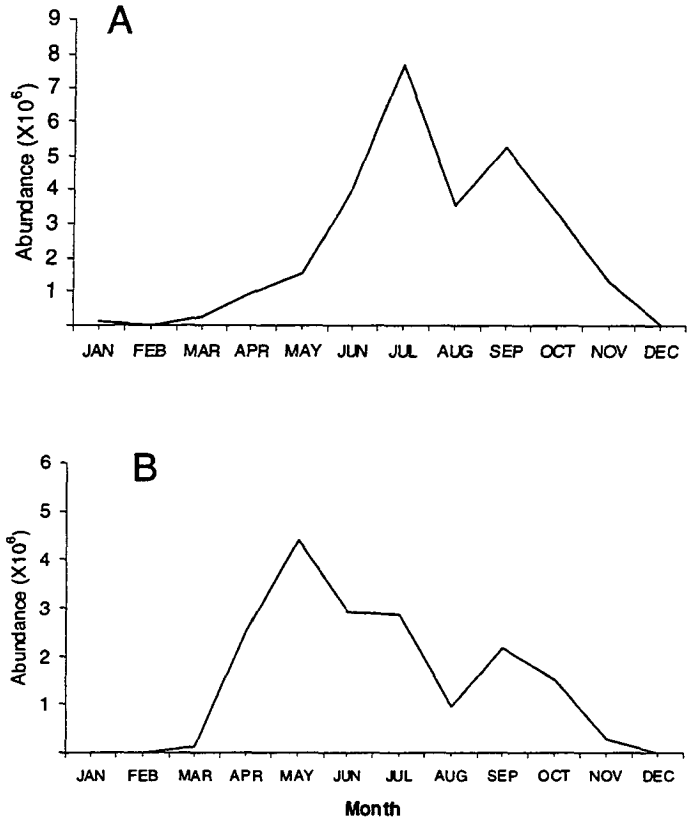

Figure 2 Seasonal abundance of northern anchovy from 1981 to 1988: (A) age 0 and (B) age 1+

Both age groups exhibited similar seasonal abundance trends, which were often bimodal with a peak in the late spring or summer, a decline in late summer and a 2nd peak in the fall (Figures 2A and 2B). Abundance was lowest in winter.

Annual Distribution

The distribution pattern of age–0 northern anchovy was typical of that of marine species; in most years the highest CPUEs were in Central Bay (Figure 3), whereas South and San Pablo bays had the next highest CPUEs. In dry years (1981, 1987–1992, and 1994), the South Bay tended to have the 2nd highest CPUE and in wet years (1980, 1982, and 1983) San Pablo Bay had the 2nd highest CPUE.

Age–1+ northern anchovy had a similar annual distribution but unlike age–0 fish, the South Bay CPUE of age–1+ fish tended to be greater than the CPUE in San Pablo Bay, especially after 1984, regardless of water year type (Figure 4).

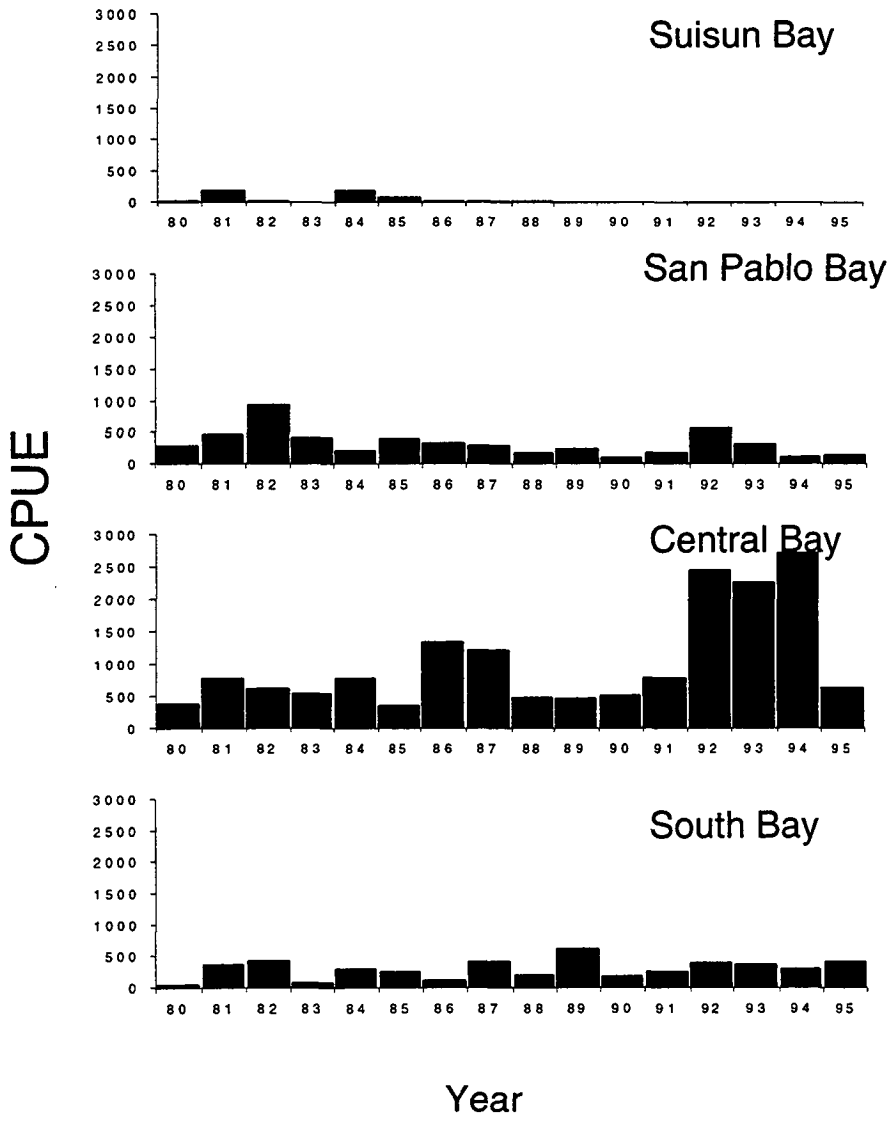

Figure 3 Annual distribution of age–0 northern anchovy by region. Values are the average CPUE for February to October.

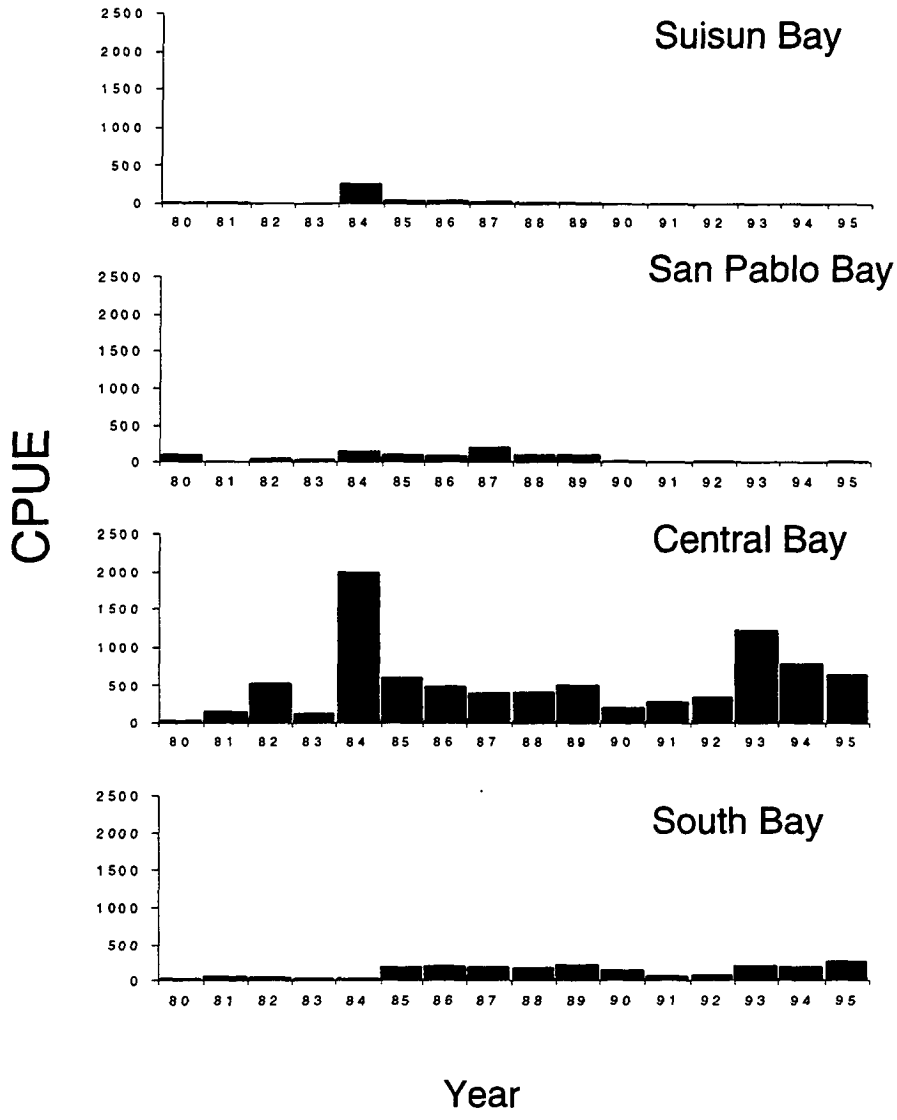

Figure 4 Annual distribution of age–1+ northern anchovy by region. Values are the average CPUE for February to October.

Seasonal Distribution

Age–0 northern anchovies had relatively low densities in winter, increasing numbers in spring, a peak in summer, and a decrease in fall (Figure 5). This pattern held for all bays except Central Bay, where a 2nd CPUE peak occurred from September to October. The greatest densities occurred in Central, San Pablo, and South bays. Only in late summer were they collected in appreciable numbers in Suisun Bay.

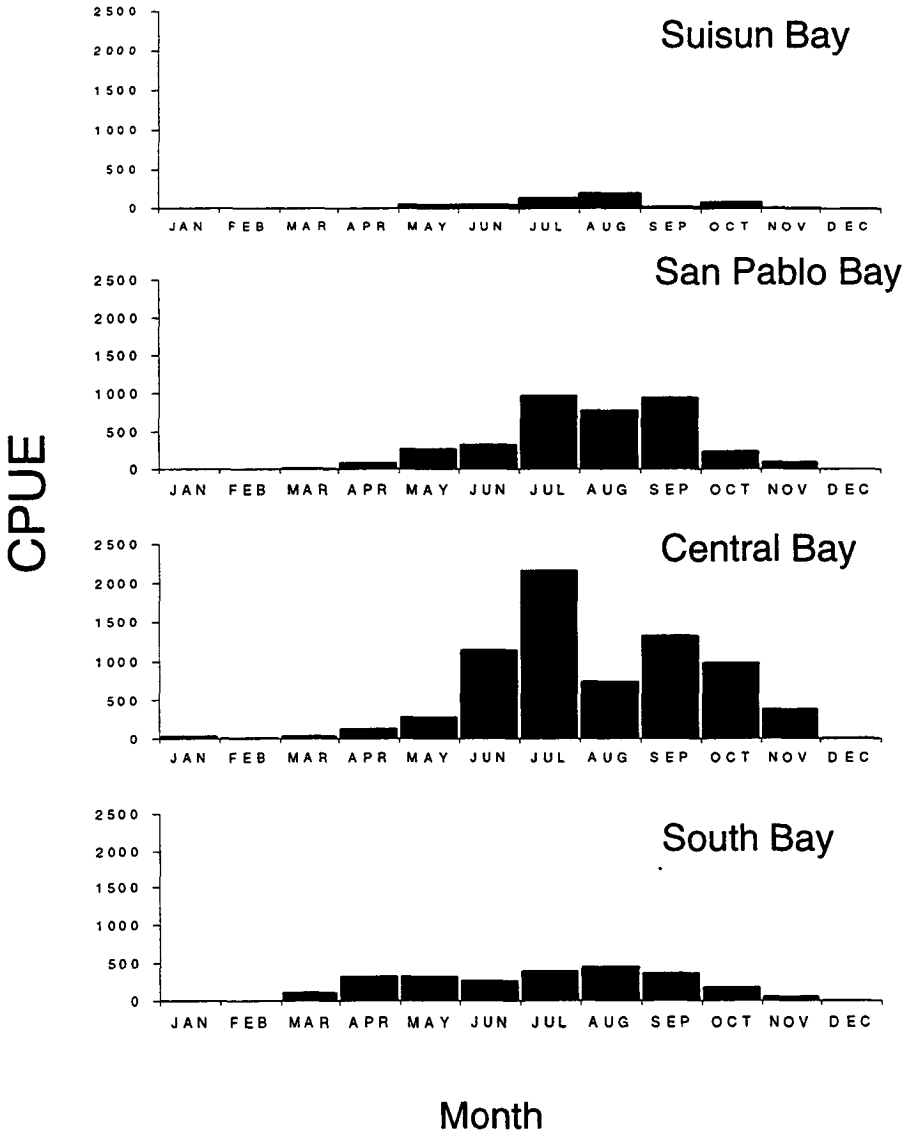

Figure 5 Seasonal distribution of age–1+ northern anchovy by region. Values are the average CPUE for 1981 to 1988.

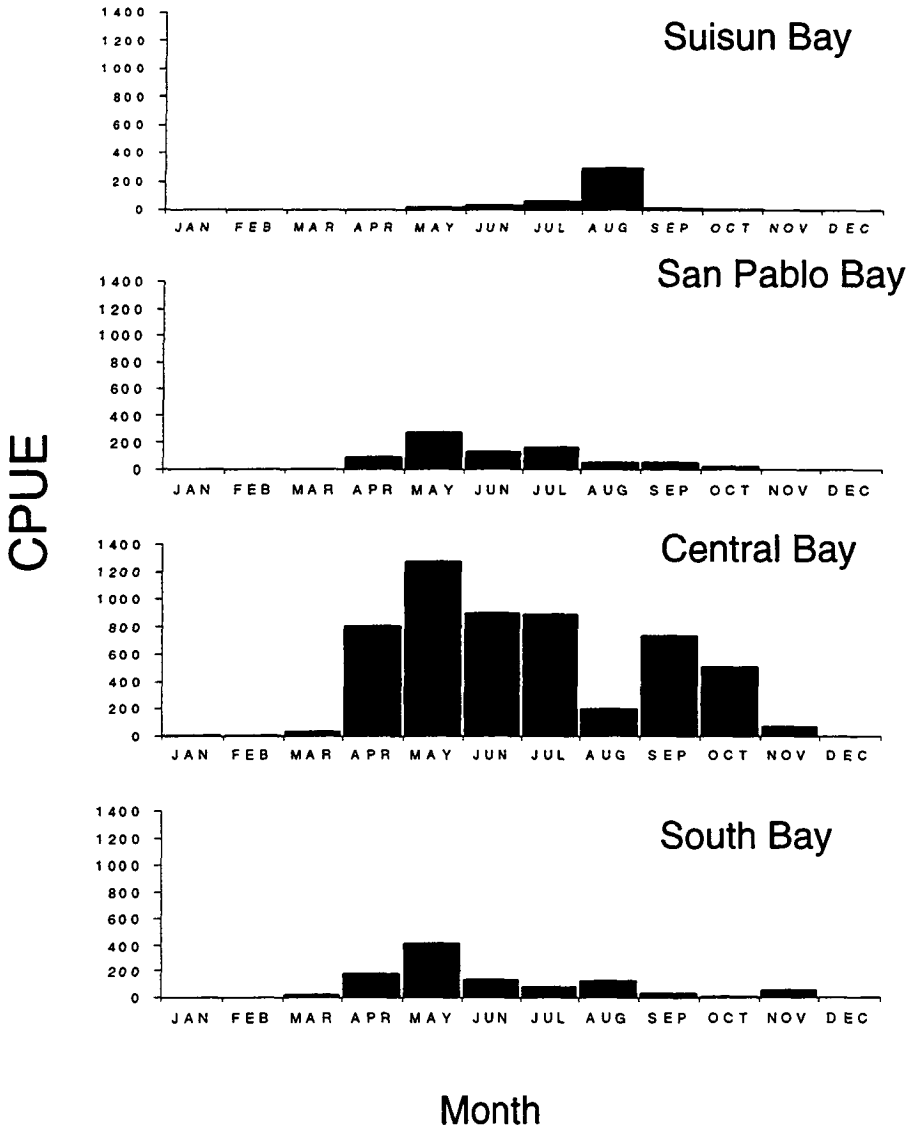

Figure 6 Seasonal distribution of age–0 northern anchovy by region. Values are the average CPUE for 1981 to 1988.

The pattern of seasonal distribution for age–1+ northern anchovies was similar to that of the age 0, but age–1+ fish were more concentrated in Central Bay than age–0 fish (Figure 6).

Temperature and Salinity

Most northern anchovies were collected between 13 and 21 °C (Figures 7A and 8A). They entered the estuary when the average temperature in Central Bay rose above about 13 °C, which typically happened in late winter, and they left in late fall, when the temperature dropped below about 13 °C. The mean temperature at which age–0 fish were found, 17.2 °C, was slightly warmer than the mean for age–1+ fish, 16.0 °C.

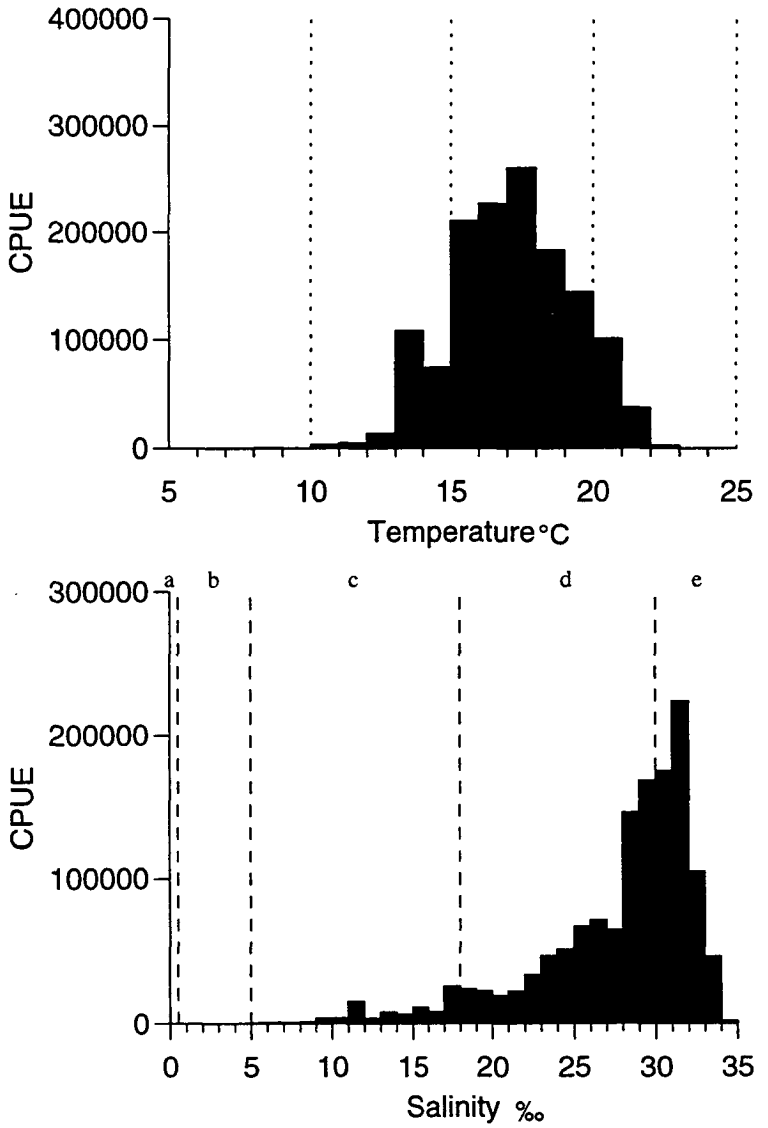

Figure 7 Temperature and salinity distributions of age–0 northern anchovy. The vertical lines on the salinity graph mark the boundaries of the Venice system ranges: (a) limnetic, (b) oligohaline, (c) mesohaline, (d) polyhaline, and (e) euhaline.

Northern anchovies were found over wide salinity ranges (Figures 7B and 8B). Both age classes were found primarily in polyhaline to euhaline ranges and the means for both were very close: 27.3‰ for age 1+ and 27.6‰ for age 0.

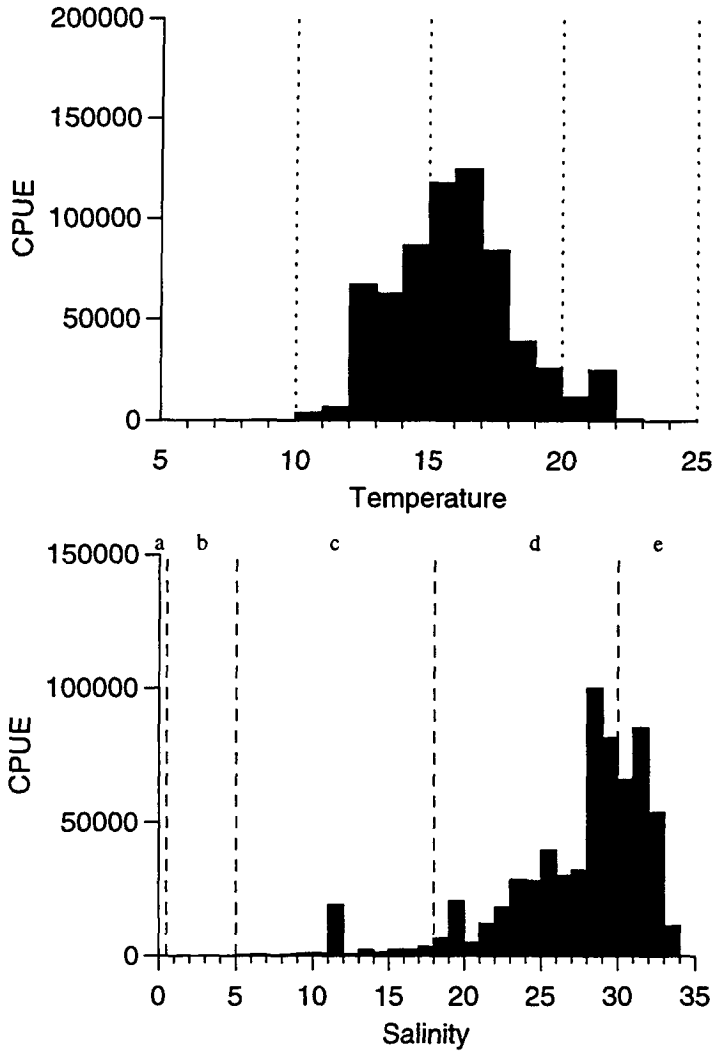

Figure 8 Temperature and salinity distributions of age–1+ northern anchovy. The vertical lines on the salinity graph mark the boundaries of the Venice system ranges: (a) limnetic, (b) oligohaline, (c) mesohaline, (d) polyhaline, and (e) euhaline.

Discussion

Northern anchovies follow a predictable pattern of seasonal abundance in the estuary. They move in from the ocean throughout the spring and summer. Peak abundance is generally in late spring but abundance is often bimodal with a 2nd peak in the fall. Abundance is lowest in winter. Despite great fluctuations in abundance, the northern anchovy is the most numerous fish species in the estuary, comprising from 74% to 98% of the total midwater trawl catch. Most northern anchovy are found in the polyhaline to euhaline waters of the estuary.

Northern anchovies in this estuary are part of the central population (Vrooman and others 1981, Haugen and others 1951). The size and proximity of the ocean schools to the estuary, and therefore, the potential

for estuary use, depend upon oceanic conditions. Immigration into the estuary may be in response to the higher temperatures found in it that may allow earlier spawning opportunities than would be possible in the ocean. The timing of estuarine entry and exit corresponded with seasonal changes in the temperature of Central Bay.

Seasonal changes in the temperature differential between the ocean and Central Bay may also partly explain the 2nd peaks in CPUEs of both age classes that occurred in many years in fall. Although the estuary usually has higher temperatures than the ocean, ocean temperatures may be higher in summer and fall. The higher ocean temperature appears to correspond to the decreased CPUE in the estuary. As ocean temperatures decrease in late fall, the CPUE in the estuary increases again. The increased fall abundance can also explain the 2nd spawning mode because northern anchovy spawn all year and spawning intensity should, therefore, be a function of the number of spawners in an area.

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